In-Beam Gamma-Ray Studies of Neutron-Rich N~20 Nuclei in Fragmentation Reactions

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A two-step fragmentation/knockout experiment was conducted at the National Superconducting Cyclotron Laboratory, Michigan State University, to produce neutron-rich sodium, neon, and fluorine nuclei, among others. The goal was to measure excited states in these neutron-rich A~30 nuclei to study the effects of valence nucleon interactions (e.g. the p-n $V_{\sigma\tau}$) and provide information on the underlying character of these nuclei; whether single-particle or collective.

In this experiment a 140 MeV/A ^{48}Ca primary beam bombarded an 846 mg/cm^2 ^{9}Be target to produce a "cocktail" of secondary beams (^{29}Na/^{30}Mg/^{32}Al and ^{32}Mg/^{33}Al/^{35}Si). The secondary beams, transported by the A1900 spectrometer [1], underwent fragmentation/knockout reactions on a second 565 mg/cm^2 ^{9}Be target located at the center of the Segmented Germanium Array (SeGA) [2], which was used to measure the prompt gamma-ray decays of specific fragments detected at the S800 spectrograph [3] focal plane and identified by their time of flight and energy loss (Fig. 1). In addition, it was possible to select a particular incoming fragment beam from the "cocktail" of secondary beams using time of flight. Thus we were able to unambiguously determine on an event-by-event basis both the incoming beam and the outgoing final product. This allows us to study the population of excited states in the same nucleus produced in different reactions.

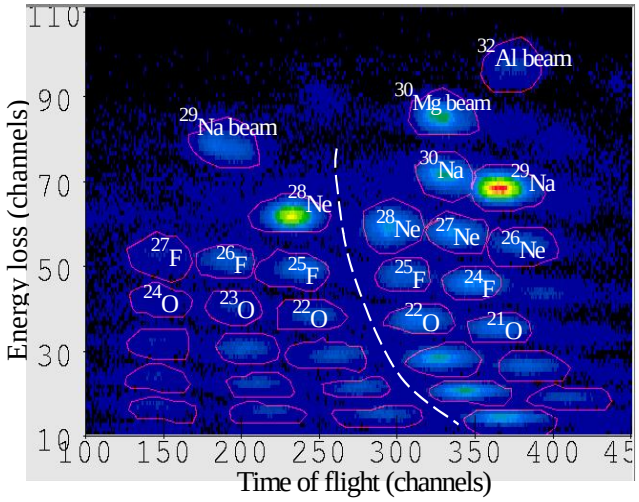

Fig. 1. Particle identification spectrum. The dashed line separates fragments produced by ^{29}Na from those originated from ^{30}Mg/^{32}Al beams.

New high quality data were obtained on excited states in a range of neutron-rich nuclei, e.g. ^{30,31}Na, ^{28,29,30}Ne, and ^{25,26}F. Here we present preliminary data on ^{30}Na. This nucleus was produced by the ^{30}Mg, ^{32}Al and ^{33}Al secondary beams. Fig. 2 shows the Doppler-corrected prompt gamma-ray spectra emitted by ^{30}Na produced from ^{32}Al (two-proton knockout reaction) and ^{30}Mg (n-p "charge-exchange" reaction). The two reactions give very different gamma-ray decay spectra (intensities and transitions) suggesting a strong dependence on the structure of the incoming beam and the reaction mechanism.

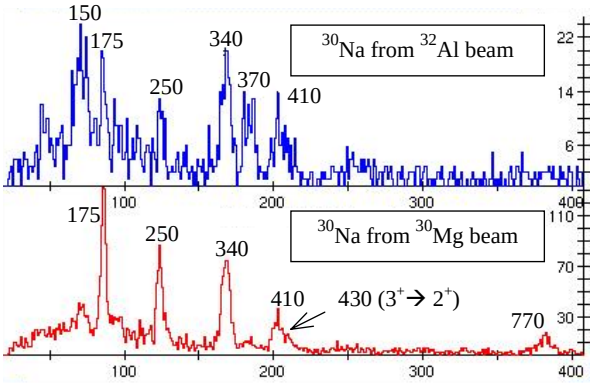

Fig. 2. Doppler-corrected gamma-ray energy spectra of ^{30}Na produced by ^{32}Al and ^{30}Mg beams. The energy uncertainty is +/- 5 keV.

For ^{30}Na produced from ^{30}Mg we had sufficient statistics to measure gamma-gamma coincidences. In this case all the transitions (175, 250, 340, 410, and 770 keV) were observed to be in coincidence and hence belong to the same decay chain, giving clues of a possible collective deformed structure. A transition at 430 keV (3+ → 2+) was reported in the literature from a Coulomb excitation experiment, but its intensity was not observed to be very high in this data set.

Analysis is in progress. Data on ^{30}Na and neighboring nuclei will be compared with shell model calculations such as the Monte Carlo Shell Model (MCSM), using "normal" configurations (USD model) and "intruder" configurations (SDPF-M model) [4].

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[3] D. Bazin *et al.*, Nucl. Instrum. Meth. B 204, 629 (2003)
[4] Y. Utsuno *et al.*, Phys. Rev. C 70, 044307 (2004)